The Information Content of the Short End of the Term Structure of Interest Rates

*Marco Rossi**

* Bank of England, Threadneedle Street, London EC2R 8AH.

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Abstract

This paper analyses two related questions on short-term interest rate expectations. First, whether the expectations theory of the term structure of interest rates holds at shorter horizon and, secondly, whether there is useful information in shorter-term interest rates. It uses both the slope of the yield curve (spread analysis) and forward rates within a general vector error correction framework and compares results from gilt yields and interbank rates. It finds that only London interbank rates are unbiased estimators of future interest rates outcomes and that, although current yields contain some information about future spot yields, this is not as much as in interbank rates.

1 Introduction

Market-determined interest rates are important indicators for monetary policy since they can give some indication of market expectations of future policy. Although previous work in the Bank has estimated yield curves from gilt prices and found that these give useful information about long-term expectations, the value of such yield curves at short horizons - below two years - is open to question.[1] This paper analyses two related questions on short-term interest rate expectations. First, whether the expectations theory of the term structure of interest rates holds at shorter horizons and, secondly, whether there is useful information in shorter-term interest rates for predicting future spot rates. In particular, it compares the relative performance of the short end of the Bank yield curve and traded London interbank rates at various maturities.[2]

Since the adoption of the efficient market paradigm in finance, the question of whether or not the expectations of future short-term interest rates are the dominant force determining current long-term interest rates has dominated the empirical literature. Methodological approaches vary from using the spread as predictor of future movements in spot rates [Campbell and Schiller (1991) among others] to testing forward rates as unbiased predictors of future spot rates [Fama (1984), Mishkin (1988) and Dahlquist and Jonsson (1994) among others].[3]

The empirical evidence is rather mixed and somewhat country-specific. For the United States, the expectations hypothesis is largely rejected, particularly at the short end [Shiller (1979), Campbell and Shiller (1987), (1988), (1991) and Shea (1992)]. For other countries, the expectations hypothesis is not rejected [Hardouvelis (1994), Breedon and Brookes (1994) for the United Kingdom]. However, for the United Kingdom, it shows some signs of weakness at the

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[1] A Gilt is a coupon-bearing UK government bond.

[2] The Bank of England produces this data set using the method proposed by Svensson (1994). This method involves deriving and fitting a discount function starting from a specific functional form for the implied forward rate curve. For further details see Anderson *et al* (1996).

[3] This literature has focused on testing the joint hypothesis of risk neutrality and rational use of all available information. If this joint hypothesis is accepted by the data, markets are, then, considered efficient in the sense that risk premia and, simultaneously, expected returns to speculators are zero. However, the rejection of this joint hypothesis does not necessarily imply market inefficiency. For instance, agents can be risk averse, and therefore fail the test for risk neutrality, without giving rise to arbitrage opportunities.

short end of the maturity spectrum [Cuthbertson (1992) and Hurn, Moody and Muscatelli (1994)].

In this paper the expectations theory of the term structure is tested on both fitted yields and LIMEAN rates for short-term maturities for the period 1982:7 to 1994:12 (1995:4 for yields) by using two different approaches. First, actual spreads are used to predict future changes in spot interest rates. Second, implicit forward rates are tested as unbiased predictors of corresponding future spot interest rates.[4] In addition to the analysis of the single series, cross-series (LIMEAN rates/ yields) comparisons are also carried out. The latter might tell us more about the relationship between interbank rates and yields, especially if we want to use one of them as a predictor of future outturns of the other.

The rest of the paper is organised as follows. Section 2 describes the data and summarises the characteristics of the spot rate series. Section 3 reports the results of the spread analysis, while Section 4 discusses the use of forward rates and tests their properties as unbiased estimators of future spot rates. Section 5 concludes. The Appendix contains all tables and charts.

2 Data

The interest rates considered in this study are the London Interbank Middle Market Rates (LIMEAN) and fitted gilt yields at the short end of the respective term structures.

LIMEAN rates. The data set consists of end-of-month one, three, six and twelve-month London Interbank Middle Market Rates over the period 1982:7 to 1994:12. From these, implied forward rates are computed. The latter correspond to interest rates with three-month maturity three months ahead and with six-month maturity six months ahead.

Gilt yields. For this study, the data set consists of end-of-month observations of zero-coupon yields with six, twelve, 18 and 24 months to maturity over the

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[4] Given the definition of forward rates in terms of spot rates, there is a very strict relationship between the two approaches used to test the expectations theory of the term structure of interest rates.

period 1982:7 to 1995:4.[5] The implied forward rates correspond to spot interest rates with six months to maturity six, twelve and 18 months ahead.

Some summary statistics for the six and twelve-month spot LIMEAN rates and six and twelve-month spot gilt yields, which have been adjusted by subtracting the base rate, are reported in Tables 1 to 4.

An interesting feature emerging from the data is that the LIMEAN rates are at a slight *premium* over the base rate (around 4-5 basis points), while the gilt yields are at a relatively high *discount* to the base rate (between 25 and 60 basis points). This probably reflects the different credit risk involved in an investment in the interbank market as compared to one in the gilt market.

Unit root tests on the unadjusted series are employed to establish the order of integration of each interest rate. Table 5 reports the Dickey Fuller Test for LIMEAN spot and forward rates and the spreads. All LIMEAN rates turn out to be I(1), while the spreads are I(0). Table 6 reports the Augmented Dickey Fuller Test for gilt spot and forward yields and the spreads. Again all yields turn out to be I(1). However, in this case the spreads are not all unambiguously I(0). Given the low power of the ADF test, the spectral density of the spreads is considered to help in deciding whether to accept the hypothesis of stationarity or not. On the basis of the spectral analysis (charts are shown in the Appendix) it is clear that these are borderline cases. However, stationarity was accepted.[6]

3 Spread analysis

In this section, I use the spread analysis proposed by Campbell and Shiller (1991) to investigate the predictive power of short-term interest rates.

The expectations theory of the term structure suggests that long-term interest rates should reflect expected future short-term interest rates. This can be written as:

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[5] The difference between this set of data and that for LIMEAN rates is only four observations none of which appears to be an outlier.

[6] Spectral densities were produced by using Microfit 3.0.

$$R_t^n = \frac{m}{n} \sum_{i=0}^{\frac{n-m}{m}} E_t R_{t+mi}^m \qquad n > m \tag{3.1}$$

It says that the n-period interest rate R_t^n is given by the average of the current and expected m-period rates R_{t+mi}^m up to the (n-m)-period. It follows from this that, for example, an upward-sloping yield curve suggests that investors expect higher spot rates to prevail in the future.

A simple measure of the shape of the yield curve - ie investors' expectations - is given by the yield spread, $S_t^{n,m}$, between a long-term bond and a shorter-term bond at a certain point in time. The expectations theory of the term structure implies that the current spread is an optimal forecast of changes in future interest rates, optimal in the sense that interest rate forecasts are unbiased estimates of future outcomes. From **(3.1)**, we can express the spread as a forecast of future changes in interest rates in two different ways:

$$\frac{m}{n} S_t^{n,m} = E_t R_{t+m}^{n-m} - R_t^n \tag{3.2}$$

where R_{t+m}^{n-m} indicates the yield on a n-period bond when the first m periods have elapsed. The current yield spread between an n-maturity rate R_t^n and an m-maturity rate R_t^m should predict the m-period change in yield on the longer-term bond. If the yield on a n-period bond is expected to rise over the next m-periods, we should expect the n-period bond to have a higher yield than the m-period one.

Alternatively:

$$S_t^{n,m} = E_t \sum_{i=1}^{\frac{n-m}{m}} (1 - \frac{m}{n} i) \Delta^m R_{t+mi}^m \tag{3.3}$$

where $\Delta^m R^m_{t+m} = R^m_{t+m} - R^m_t$. In this case, the spread is interpreted as a forecast of the change in short-term (m-period) interest rates over n periods.[7]

From equations (3.2) and (3.3), two tests can be structured in order to test both whether the expectations theory of the term structure of interest rates holds at shorter horizons and whether there is useful information in shorter-term interest rates for predicting future spot rates.

We can regress ($R^{n-m}_{t+m} - R^n_t$) onto the maturity-specific spread $\frac{m}{n} S^{n,m}_t$ plus a constant and test for the constant to be zero and the spread coefficient to be one:

$$R^{n-m}_{t+m} - R^n_t = \alpha + \beta\left[\frac{m}{n-m}\left(R^n_t - R^m_t\right)\right]$$

TEST 1:

$$H_0:\begin{cases}\alpha=0\\ \beta=1\end{cases} \text{ and } H_0:\{\beta=0$$

For instance, the spread between a twelve-month rate and a six-month rate today would predict the gap between the six-month rate six months ahead and the twelve-month rate today - that is, the six-month change in yield on the twelve-month bond.

Alternatively we can regress the spread $S^{n,m}_t$ on the sum of the changes in short-term rates over m periods and test for the spread coefficient to be one:

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7 It is worth noticing that, for any particular values of m and n, the fact that equation (3.2) holds does not necessarily imply that equation (3.3) should hold. Accordingly the coefficients of the actual spread in Tests 1 and 2 below should not necessarily coincide in the estimations.

TEST 2:

$$\sum_{i=1}^{\frac{n-m}{m}}\left(1-\frac{mi}{n}\right)\Delta^{m}R^{m}_{t+mi}=\alpha+\beta\,(R^{n}_{t}-R^{m}_{t}) \qquad where\ \Delta^{m}R^{m}_{t+m}=R^{m}_{t+m}-R^{m}_{t}$$

$$H_0:\begin{cases}\alpha=0\\ \beta=1\end{cases} \quad \text{and } H_0:\{\beta=0$$

In this case, the spread between a twelve-month rate and a six-month rate today would predict the sum of changes in the six-month yield over six months.

The value of β in these tests measures by how much future spot rates move for a given value of the current spread. In both tests, the hypothesis H_0:{β=1 tells us whether there is a one-to-one relationship between the current spread and changes in future spot rates (unbiasedness), whereas the hypothesis H_0:{β=0 indicates whether future spot rates are at least related to the current spread (information content).

3.1 Empirical results

This section reports the results of the empirical analysis on the LIMEAN rates and gilt yields using the two tests above. Moreover 'cross-series' tests (yield spreads against future LIMEAN changes and *vice versa*) are also performed to consider the extent to which current yield (LIMEAN rate) spreads contain information about future movements in interbank rates (fitted yields). The issue is whether, after using a scaling factor, looking at the short end of the estimated yield curve (LIMEAN rate curve) can provide 'useful' information about future movements in short-term interbank rates (yields).

Regressing the appropriate *perfect foresight spread* - that is, the forecast of changes in future short-term rates - onto the actual spread should yield a slope coefficient of 1. In the Appendix some scatter plots of actual and *perfect foresight* spreads are presented for illustrative purposes. In some of them a clear positive relationship between the two series exists. The values of the slope coefficients are considered in the analysis below.

According to the expectations hypothesis of the term structure long-term interest rates should reflect expected future short-term interest rates. If the forecast horizon is longer than the period between two successive observations - ie one month for our data set, long-term interest rates are not independent. Successive observations of the long rate are in part based on the same information. This makes the error term in the proposed regressions (tests) a moving average process whose order is given by the length of the forecast horizon minus one. In the estimations a corrected variance-covariance matrix, as suggested in Newey and West (1987), is computed to take this feature of the regression residuals into account.

LIMEAN rates

The results from Test 1 (Table 7a-c) indicate that, although the point estimates for the slope coefficients deviate substantially from one, the theoretical value, the hypothesis $\beta=1$ is accepted at the conventional significance level. However, the large standard errors imply acceptance of the hypothesis $\beta=0$ too. Besides the variation in the current spread explains only a relatively small percentage of the variation in future spot rates - R^2 is between 2.3% and 6.3%.

By contrast the results from Test 2 (Table 7a-c) indicate that current spreads are not only informative about future changes in spot rates ($\beta\neq0$), but also unbiased predictors of their future movements ($\beta=1$). Standard errors are generally of smaller size and R^2s are much higher than those in Test 1.

Yields

The results from Test 1 (Table 7a-c) show that all point estimates for the slope coefficients are very close to zero and, indeed, not significantly different from zero at conventional significance levels. However, the large standard errors imply that some of them (those marked with a *) cannot be considered significantly different from one either. Moreover the amount of variation in future spot yields explained by the variation in current spreads is negligible.

Test 2 (Table 7a-c) confirms the results from Test 1 as far as unbiasedness is concerned - the slope coefficients are significantly different from the theoretical value of 1. However, and in contrast with the results for Test 1, the β coefficients are significantly different from zero and R^2s are reasonably high (between 11% and 25%) implying that, although biased predictors, yields spreads contain some information about changes in future spot rates.

LIMEAN rate and yield spread (cross-series tests)

The results for the common maturity (six-month rates) are presented in Table 7a-c. Both tests indicate that future movements in interbank interest rates are not at all in line with what the yield spread would predict. Moreover, the slope coefficients are not significantly different from zero. By contrast, when LIMEAN rate spreads are used to predict future changes in fitted yields, we cannot reject the expectations hypothesis. Although standard errors are large, the slope coefficient turns out to be significantly different from zero too, at least in Test 2. Besides the amount of variation in future yields accounted for by current LIMEAN spreads (13%) is more than double that when yields are used to predict future movements in spot LIMEAN rates (6%).

As pointed out by Campbell and Shiller (1991), single equation tests of the expectations hypothesis have some disadvantages. First, the estimation procedure necessary for correcting for the MA process in residuals is less 'precise' the larger the degree of overlap relative to the sample size. Second, these tests do not offer any evidence of the long-term relationship between the actual spread and the theoretical *perfect foresight spread*. These are some of the reasons why many authors have tested the expectations hypothesis by using the spread analysis, but by adopting a vector autoregressive framework [Campbell and Shiller (1987, 1988), Cuthbertson (1992) and Hurn, Moody and Muscatelli(1994)].[8]

4 Efficiency in forward markets

Another strand of the empirical literature on testing the predictive power of short-term interest rates is concerned with testing forward interest rates as unbiased predictors of future spot interest rates.

The first part of this section points out that the traditional vehicles for testing the predictive power of forward rates and the set of hypotheses considered are a special case of a more general framework developed by Moore (1994) in the

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[8] This avenue is not followed in this paper.

context of foreign exchange forward markets. In the second part, the predictive power of forward rates is tested using this general Error Correction Model specification.

4.1 A general ECM specification

The following sets of regression equations and null hypotheses represent the traditional vehicles for testing the predictive power of forward rates.[9]

(1) The level regression

This approach consists simply in regressing the level of the realised future spot rate on the current forward rate:

$$r_{t+1} = \alpha_1 + \beta_1 f_t + u_{t+1} \tag{4.1}$$

$$H_0: \begin{cases} \alpha_1 = 0 \\ \beta_1 = 1 \end{cases}$$

where r_{t+1} is the spot interest rate on a one-period zero-coupon bond purchased at time $t+1$ and f_t is the corresponding one-period forward rate at time t.[10]

The basic problem with this regression equation is that spot and forward rates are usually non-stationary. Therefore, the estimated standard errors from equation (**4.1**) and, more generally, any statistical inference drawn from the results should be considered with caution.

(2) The simple difference equation

In this case the realised change in future spot rates is regressed on the current

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[9] The same set of equations has also been used to test for market efficiency in foreign exchange markets with forward and spot interest rates replaced by forward and spot exchange rates [Frenkel (1976), Cumby and Obstfeld (1981) and Hakkio and Rush (1989) among many others].

[10] The data set used in this paper contains yields with six, twelve, 18 and 24-month maturity. Accordingly in this paper r_{t+1} may indicate the interest rate on a zero-coupon bond purchased at time $t+1$ and maturing after six, twelve, 18 and 24 months. The same applies to one, three, six and twelve-month LIMEAN rates.

forward premium:

$$\Delta r_{t+1} = \alpha_2 + \beta_2 (f_t - r_t) + u_{t+1} \tag{4.2}$$

$$H_0 \begin{cases} \alpha_2 = 0 \\ \beta_2 = 1 \end{cases}$$

where $\Delta r_{t+1} = r_{t+1} - r_t$

(3) <u>The Error Correction Model (ECM)</u>

The departure point for the approach considered here is that a cointegrated time-series model has an error correction model representation [Engle and Granger (1987)]:

$$\Delta r_{t+1} = \beta_3 (r_t - \beta_1 f_{t-1} - \alpha_1) + \beta_4 (f_t - f_{t-1}) + \varepsilon_{t+1} \tag{4.3}$$

$$H_0 : \{-\beta_3 = \beta_4 = 1$$

where α_1 and β_1 are the same parameters as in equation **(4.1)**.

This specification indicates that any deviation from long-run equilibrium for the relationship between the forward and the spot rates - first term on the right-hand side of equation **(4.3)** - is taken immediately into account when predicting future spot rates. Moreover agents are assumed to use all information given by changes in forward rates.

However a more general specification for the ECM is possible. Consider a Vector Autoregressive (VAR) model with cointegrated variables which can be written in the following form:

$$\Delta x_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \alpha \beta' x_{t-1} + \varepsilon_t \tag{4.4}$$

where x_t is a Nx1 vector of cointegrated variables, α is the adjustment coefficient vector (loading factor), β is the cointegrating coefficient vector, Γ_i

is an NxN matrix with N the number of variables and p is the lag order.[11] With this model we can test the hypothesis of cointegration (long-run relationship) between the spot and the corresponding forward rates while, simultaneously, studying short-run fluctuations in the series.

In our case $x_t = (r_{t+1}, f_t)$, the spot rate one period ahead and the current forward rate. We can rewrite **(4.4)** in extensive form as follows:

$$\begin{bmatrix} \Delta r_{t+1} \\ \Delta f_t \end{bmatrix} = \begin{bmatrix} \mu_r \\ \mu_f \end{bmatrix} + \begin{bmatrix} a_{r,1} & b_{r,1} \\ a_{.,1} & b_{f,1} \end{bmatrix} \begin{bmatrix} \Delta r_t \\ \Delta f_{t-1} \end{bmatrix} + \begin{bmatrix} a_{r,2} & b_{r,2} \\ a_{f,2} & b_{f,2} \end{bmatrix} \begin{bmatrix} \Delta r_{t-2} \\ \Delta f_{t-2} \end{bmatrix} + \cdots\cdots\cdots \tag{4.5}$$

$$\cdots\cdots\cdots + \begin{bmatrix} a_{r,p-1} & b_{r,p-1} \\ a_{f,p-1} & b_{f,p-1} \end{bmatrix} \begin{bmatrix} \Delta r_{t-p+1} \\ \Delta f_{t-p} \end{bmatrix} + \begin{bmatrix} \alpha_r \\ \alpha_f \end{bmatrix} [1 - \beta_1] \begin{bmatrix} r_t \\ f_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{r,t} \\ \varepsilon_{f,t} \end{bmatrix}$$

where μ is a 2x1 vector of constants such as $\mu = \alpha\beta_0 + \alpha_\perp\delta$ and $\alpha_\perp$ is a 2x1 vector orthogonal to α; δ is a scalar. In this way the vector of constraints is partitioned into the constant $\alpha\beta_0$ which appears inside the cointegrating vector and the constant $\alpha_\perp\delta$ which appears in the ECM outside the cointegrating vector. If we assume that there are no deterministic linear trends in either the spot or forward rate series, we should impose $\alpha_\perp\delta = 0$.[12]

With these constraints we can rewrite **(4.5)** as:

$$\Delta r_{t+1} = \alpha_r(r_t - \beta_1 f_{t-1} - \beta_0) + \sum_{i=0}^{p-1} a_{r,i}\, \Delta r_{t-i} + \sum_{i=1}^{p-1} b_{r,i}\, \Delta f_{t-i} + \varepsilon_{r,t} \tag{4.6}$$

$$\Delta f_t = \alpha_f(r_t - \beta_1 f_{t-1} - \beta_0) + \sum_{i=0}^{p-1} a_{f,i}\, \Delta r_{t-i} + \sum_{i=1}^{p-1} b_{f,i}\, \Delta f_{t-i} + \varepsilon_{f,t} \tag{4.7}$$

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[11] See Hamilton (1994).

[12] This 'restriction $\mu = \alpha\beta_0$ on the constant therefore implies that the constant term is restricted to the cointegrating vector only. An unrestricted constant [...] allows for linear deterministic trends in the levels of the spot and forward rate time series' [Moore (1994)].

In terms of the ECM specified in equations **(4.6)** and **(4.7)**, long-term and short-term unbiasedness would translate in the following conditions on the spot and forward rate series and parameters. For long-run unbiasedness we require:

a) Spot and forward rates to be cointegrated. If forward rates are optimal forecasts of realised spot rates and the information set includes all earlier observations of the series, we should expect a stable relationship between forecast and realised series. Cointegration is a precondition for the existence of such a stable relationship and, hence, it is a necessary condition for unbiasedness.
b) $\beta_0 = 0$ and $\beta_1 = 1$

For short-run unbiasedness, in addition to a) and b), we require that:

c) $a_{r,i} = b_{r,i} = 0$, ie no short-run dynamics in the spot equation, $\forall\, i$
d) $\alpha_r = -1$

These last two conditions can be immediately derived once we impose a) and b) on equation **(4.6)** which would be written as:

$$r_{t+1} - f_{t-1} = (\alpha_r + 1)\,(r_t - f_{t-1}) + \sum_{i=0}^{p-1} a_{r,i}\,\Delta r_{t-i} + \sum_{i=1}^{p-1} b_{r,i}\,\Delta f_{t-i} + \varepsilon_{r,t} \qquad \textbf{(4.8)}$$

For unbiasedness the forecast error should not be auto-correlated; therefore conditions c) and d) should be satisfied.

It is clear that, as was the case in Section 3, the information content of forward rates can be tested by considering the additional hypothesis $H_0 : \beta_1 = 0$.

The most striking feature of the ECM used in the empirical literature - equation **(4.3)** - when compared with the ECM as defined by equations **(4.6)** and **(4.7)** is that it contains a single equation. Johansen (1992) showed that there are no efficiency losses from single-equation estimation in cointegrated systems if one variable turns out to be weakly exogenous.

However, if the forward rate is weakly exogenous, ie $\alpha_f = 0$, the efficient estimates are obtained from:

$$\Delta r_{t+1} = h_0 \Delta f_t + \alpha_r (r_t - \beta_1 f_{t-1} - \beta_0) + \sum_{i=0}^{p-1} a_i \Delta r_{t-i} + \sum_{i=1}^{p-1} b_i \Delta f_{t-i} + u_t \quad \textbf{(4.9)}$$

where h_0 , a_i and b_i are parameters.

The parameters in **(4.9)** are related to those in **(4.6)** and **(4.7)** as follows:

$$h_0 = \sigma_{rf} \sigma_{ff}^{-1}$$

$$a_i = a_{r,i} - \sigma_{rf} \sigma_{ff}^{-1} a_{f,i}$$

$$b_i = b_{r,i} - \sigma_{rf} \sigma_{ff}^{-1} b_{f,i}$$

$$u_t = \varepsilon_{r,t} - \sigma_{rf} \sigma_{ff}^{-1} \varepsilon_{f,t}$$

where σ_{rf} , σ_{rr} and σ_{ff} are the elements of the variance-covariance matrix of ($\varepsilon_{r,t}$, $\varepsilon_{f,t}$). The parameters of the forward equation do not play a role only if σ_{rf} = 0 and equation **(4.9)** collapses into equation **(4.6)**.

Let us now compare equation **(4.9)** with equations **(4.3)** and **(4.2)** respectively. Apart from short-run dynamics, the two equations **(4.9)** and **(4.3)** look similar:

- $h_0 = \beta_4$
- $\alpha_r = \beta_3$
- $\beta_0 = \alpha_1$
- β_1 is the same in both specifications

The null hypothesis $-\beta_3 = \beta_4 = 1$ tested in **(4.3)** seems to be only a test of short-term unbiasedness as defined previously in this paper - ie, $\alpha_r = -1$. Moreover, the hypothesis that $\beta_4 = 1$ - that is, $h_0 = 1$ in equation **(4.9)** - would imply that $\sigma_{rf} = \sigma_{ff}$.

By contrast if we rewrite equation **(4.9)** as:

$$\Delta r_{t+1} = -\alpha_r \beta_0 + (h_0 f_t + \alpha_r r_t) - (h_0 + \alpha_r \beta_1) f_{t-1} + \sum_{i=0}^{p-1} a_i \Delta r_{t-i} + \sum_{i=1}^{p-1} b_i \Delta f_{t-i} + u_t \quad \textbf{(4.10)}$$

equation (**4.2**), ie, the simple difference test, seems to be a particular case of equation (**4.9**) obtained only when:

- $-\alpha_r \beta_0 = \alpha_2$
- $h_0 + \alpha_r \beta_1 = 0$
- $-\alpha_r = h_0 = \beta_2 = 1$

These conditions would imply that $\beta_1 = 1$ as well. When these conditions are satisfied, unbiasdness is also satisfied. However, these conditions are assumed in equation (**4.2**) rather than tested as they should be.

4.2 Empirical results

In this section I test for the predictive power of forward rates using the ECM defined by equations (**4.6**) and (**4.7**) and the single-equation model defined in (**4.9**).

LIMEAN

Lag length of the vector autoregression. The lag length of the VAR is selected using standard information criteria. The results are as follows:

- for the forward rate corresponding to the spot rate with three months to maturities, three months ahead the lag length is p=4
- for the forward rate corresponding to the spot rate with six months to maturity, six months ahead the lag length is p=7

Cointegration analysis. It is reasonable to believe that spot and forward interest rates do not display deterministic trends; accordingly, when either of the two series are differenced, there is no need to have a drift term to describe changes in the process. This implies that the intercept term in the vector autoregressive model for cointegration enters not as an autonomous growth factor, but rather as a constant in the error correction term only. The model (**4.6**) and (**4.7**) is estimated by using the Johansen approach with a restricted constant.[13] The results are contained in Table 8.

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[13] It is only in the case of a restricted constant that inferences can be made on the constant in the cointegrating relationship.

Table 8 shows that the null hypothesis that the number of cointegrating vectors is no greater than zero (ie the series do not cointegrate) is rejected because the test statistic exceeds the critical value. The alternative hypothesis of two cointegrating vectors is also rejected; there is one cointegrating vector between the spot and the corresponding forward rates.

Test of hypothesis. A series of hypotheses on the parameters of the cointegrating vector in (4.6) and (4.7) are tested separately.

For long-run unbiasedness in forward markets:

- $H_0\!:\!\left\{\begin{array}{l}\beta_0=0\\ \beta_1=1\end{array}\right.$
- $H_0\!:\!\{\beta_1 = 1$
- $H_0\!:\!\{\beta_0 = 0$

For short-run unbiasedness in forward markets:

- $H_0\!:\!\{\alpha_r = -1$
- $H_0\!:\!\{a_{r,i} = b_{r,i} = 0$

For the information content of forward rates:

- $H_0\!:\!\{\beta_1 = 0$

Table 9a reports inference on the long and short-run relationships and the point estimates for the parameters of the cointegrating vector. The overall fit of the ECM specification, as defined in (4.6) and (4.7), is good. All coefficients in the long-run relationship have the right sign and are not significantly different from the null hypothesis values. Short-term conditions are only partially satisfied. We may conclude that the hypothesis of unbiasedness cannot be rejected for any regression confirming that forward rates are unbiased predictors of future spot rates; the shorter the maturity of the forward rate, the more precise the estimates. Moreover, β_1 is also found to be significantly different from zero (Table 9b).

Single-equation model. Table 10 reports the results from the estimation of equation **(4.9)**. Short-run dynamics - ie third and fourth term on the RHS of **(4.9)** - are not considered. Rather parameters (h_0 and α_r) indicating short-term unbiasdness are estimated. The regressions seem not to be significant, suggesting no short-term unbiasedness in forward markets. This result is consistent with the previous cointegration analysis where the hypothesis $\alpha_r = -1$ was also rejected.

Yields

Lag length of the vector autoregression. The optimal lag length for yields is found to be one for all maturities; this means that the ECM specification consists only of the error-correction term with no short-run dynamics.

Cointegration analysis. The model **(4.6)** and **(4.7)** is estimated by the Johansen procedure with a restricted constant. The results are contained in Table 8. The null hypothesis of at least one cointegrating vector is accepted in the first two cases, but rejected in the third one. Forward rates corresponding to spot rates with six months to maturity 18 months ahead and spot rates themselves fail to display a significant long-run relationship which is a necessary condition for unbiasedness. Accordingly the analysis below proceeds on the first two series only.

Test of hypothesis. The same set of hypotheses on the parameters of the cointegrating vector in **(4.6)** and **(4.7)** as for LIMEAN rates are tested. Table 9a reports inference on the long-run relationships and the point estimates for the parameters of the cointegrating vectors. In both cases the ECM specification does not seem to fit the data well. The coefficients are distant from the values predicted by the theory; the null hypotheses are largely rejected at 5% level. Forward yields cannot, therefore, be considered unbiased predictors of future spot yields. However, as shown in Table 9b, the hypothesis $H_0 : \beta_1 = 0$ is rejected indicating that forward yields are not totally uninformative.

Single-equation model. Table 10 reports the results from the estimation of equation **(4.9)**. As is the case with LIMEAN rates the entire regression seems not to be significant. In particular the hypothesis that $\alpha_r = -1$ is clearly rejected.

LIMEAN rates/yields

As far as the cross-rate comparison is concerned, we should consider two cases separately:

- Forward yields are used to predict future levels of interbank rates
- LIMEAN forward rates are used to predict future levels of fitted yields

In the former case, forward yields and spot interbank rates do not cointegrate, therefore, failing to satisfy the necessary condition for unbiasedness (Table 8).

In the latter case, forward LIMEAN rates and fitted yields cointegrate, but the conditions for unbiasedness are not satisfied (Table 9). The estimation of equation (4.9) indicates that its specification is not significant (Table 10).

5 Conclusions

The aim of this paper was twofold. First, the expectations theory of the term structure was tested on both fitted yields and LIMEAN rates for short-term maturities over the period 1982:7 to 1994:12 (1995:4 for yields) by using two different approaches: actual spreads were used to predict future changes in spot interest rates and forward rates were tested as unbiased predictors of corresponding future spot interest rates. Second, it compared the information content of short-term gilt yields and traded London interbank rates at various short maturities.

Moreover, from a methodological point of view, it was shown that a more general vector error correction model should be used when testing for unbiasedness in forward rates. All other specifications considered in the empirical literature turn out to be particular cases of this more general framework.

As far as LIMEAN rates are concerned, these results suggest that the expectations hypothesis of the term structure cannot be rejected, which would imply no arbitrage opportunities along the interbank 'yield' curve in the long run.

As far as yields are concerned, the results from the empirical analysis do not support the hypothesis of unbiasedness. This is true no matter the approach used. Actual spreads do not *accurately* predict future movements in spot yields. Most of the coefficients of actual spreads are much smaller than the theoretical value of one predicted by the expectations hypothesis of the term structure. Forward rates, moreover, appear to be biased predictors of future levels of spot rates. However, although yields failed to satisfy the conditions for unbiasedness, they are not totally uninformative. The relevant β coefficients are significantly different from zero and the variation in current spreads accounts for a non-insignificant part of the variation in future changes in spot yields.

Finally, as far as the 'cross tests' - where fitted yields are used to predict future LIMEAN rates and also LIMEAN rates are used to predict future fitted yields - are concerned, these results show that current LIMEAN rates are relatively better at predicting future spot yields than current yields at forecasting future spot interbank rates.

The fact that the expectations theory of the term structure is rejected at the short end when tested using yields is not an extraordinary result in itself. As a matter of fact, there is an ample literature showing similar results for other data sets [Hardouvelis (1994) for instance]. However, from a policy perspective, it seems more important to focus on the information contained in current interest rates rather than testing for the expectations theory of the term structure *per se*. In this respect, these results show that current short-term yields are less informative about spot yields in the future than interbank interest rates. The variation of future spot yield outcomes is accounted for by variation in current spot yields to a lesser degree than when interbank rates are considered.[14]

This evidence suggests that, although interbank interest rates are unbiased predictors of future spot yields, current yields contain some information about future spot yields, but, perhaps, not to the extent that would warrant the use of yield curves with maturities below two years in order to gauge market's expectations about nominal interest rates in the future.

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[14] When the Error Correction Model is used, this gap in the information contained in LIMEAN rates and yields, respectively, is even wider.

However, we should recognise that these results depend on the 'quality' of our fitted yields which, in turn, depends on the specification of the fitting procedure: LIMEAN rates are the observed market rates, while gilt yields are those obtained by fitting a specific functional form to the observed market gilt prices. It is, therefore, reasonable to assume that a different specification might result in a different fitted yield curve, in particular at the short end where yields are usually more volatile. It would be interesting to see whether the results obtained in this paper are robust to changes in the fitting procedure used to generate the yield data set.

APPENDIX Tables and Charts

Table 1

6-month Yield minus Base Rate %	
Mean	-0.2555
Standard Deviation	0.58879
Kurtosis	1.62089
Skewness	-0.6703
Minimum	-2.7691
Maximum	0.9687

Table 2

6-month LIMEAN rate minus Base Rate %	
Mean	0.05401
Standard Deviation	0.46984
Kurtosis	2.04418
Skewness	-0.6662
Minimum	-2
Maximum	1.375

Table 3

12-month Yield minus Base Rate %	
Mean	-0.6277
Standard Deviation	0.92582
Kurtosis	-0.3191
Skewness	-0.0339
Minimum	-2.8409
Maximum	1.50472

Table 4

12-month LIMEAN rate minus Base Rate %	
Mean	0.04426
Standard Deviation	0.69283
Kurtosis	0.41332
Skewness	0.08311
Minimum	-2.12
Maximum	1.755

Table 5 Order of integration

Series	DF Test on levels for I(0)	DF Test on first differences for I(1)
1-month spot LIMEAN	-1.0644	-10.9377*
3-month spot LIMEAN	-1.1403	-11.201*
6-month spot LIMEAN	-1.2995	-11.8149*
12-month spot LIMEAN	-1.4426	-11.15*
Forward LIMEAN (3, 3)	-1.6129	-12.8776*
Forward LIMEAN (6, 6)	-1.6852	-11.005*
Spread(12, 6)	-3.9888*	
Spread(12, 3)	-2.7849**	
Spread(12, 1)	-3.8122*	
Spread(6, 3)	-5.2885*	
Spread(6, 1)	-5.371*	
Spread(3, 1)	-6.7198*	

Notes: The critical values employed are taken from Banerjee et al. (1993), page 103.
* = significant at the 5% level.
** = significant at the 10% level.

Table 6 Order of integration

Series	DF Test on levels for I(0)	DF Test on first differences for I(1)
6-month spot yield	-1.3003	-8.5899*
12-month spot yield	-1.5741	-8.5245*
18-month spot yield	-1.7294	-8.7153*
24-month spot yield	-1.8294	-8.7801*
Forward yield (6, 6)	-2.442	-11.0095*
Forward yield (6, 12)	-2.176	-9.2575*
Forward yield (6, 18)	-2.2917	-9.2969*
Spread(24, 18)	-2.506	
Spread(24, 12)	-2.0201	
Spread(24, 6)	-2.3084	
Spread(18, 12)	-2.3015	
Spread(18, 6)	-2.754**	
Spread(12, 6)	-3.5607*	

Notes: The critical values employed are taken from Banerjee et al. (1993), page 103.
* = significant at the 5% level.
** = significant at the 10% level.

Table 7a. Spread Analysis (H_0: β=1)

Test 1

n (months)	LIMEAN m(months) 3	LIMEAN m(months) 6	Yields m(months) 6	Yields m(months) 12	Yields m(months) 18	Yields/ LIMEAN rates m(months) 6	LIMEAN rates /Yields m(months) 6
6	0.64396* (0.47412)						
12		1.4033* (0.85723)	-0.043 (0.2601)			0.31098 (0.26078)	0.54274* (0.87248)
18			0.03272 (0.4373)	-0.033* (0.624)			
24			0.05115 (0.3382)	0.272* (0.633)	0.3973* (0.554)		

Test 2

n (months)	LIMEAN m(months) 1	LIMEAN m(months) 3	LIMEAN m(months) 6	Yields m(months) 6	Yields m(months) 12	Yields/ LIMEAN rates m(months) 6	LIMEAN rates /Yields m(months) 6
3	0.93334* (0.1689)						
6	0.83638* (0.1584)	0.82198* (0.2371)					
12	0.96714* (0.1963)	1.0340* (0.2573)	1.2017* (0.429)	0.4785 (0.130)		0.26605 (0.13350)	1.185* (0.4535)
18				0.5631 (0.177)			
24				0.6634 (0.13)	0.63599* (0.31645)		

Notes: Newey and West(1987) corrected standard errors in brackets.
Constant terms estimated but not reported.
* = H_o : β = 1 is accepted at 5% significance level.

Table 7b. Spread Analysis (H_0: β=0)

Test 1		LIMEAN m(months)		Yields m(months)			Yields/ LIMEAN rates m(months)	LIMEAN rates /Yields m(months)
		3	6	6	12	18	6	6
n (months)	6	0.64396* (1.3582)						
	12		-1.4033* (1.6370)	-0.043* (-0.1653)			0.31098* (1.1925)	0.54274* (0.62207)
	18			0.03272* (0.0749)	-0.033* (-0.053)			
	24			0.05115* (0.1513)	0.272* (0.43)	0.3973* (0.717)		

Test 2		LIMEAN m(months)			Yields m(months)		Yields/ LIMEAN rates m(months)	LIMEAN rates /Yields m(months)
		1	3	6	6	12	6	6
n (months)	3	0.93334 (5.5259)						
	6	0.83638 (5.2787)	0.82198 (3.4674)					
	12	0.96714 (4.9260)	1.0340 (4.0178)	1.2017 (2.804)	0.4785 (3.679)		0.26605 (1.9929)	1.185 (2.6127)
	18				0.5631 (3.175)			
	24				0.6634 (5.118)	0.63599 (2.0097)		

Notes: t-ratio in brackets.
Constant terms estimated but not reported.
* = H_0 : β = 0 is accepted at 5% significance level.

Table 7c. Spread Analysis (R^2)

Test 1		LIMEAN m(months)		Yields m(months)			Yields/ LIMEAN rates m(months)	LIMEAN rates /Yields m(months)
		3	6	6	12	18	6	6
n (months)	6	2.3%						
	12		6.1%	0.045%			2.5%	0.8%
	18			0.014%	0.01%			
	24			0.024%	0.56%	1%		

Test 2		LIMEAN m(months)			Yields m(months)		Yields/ LIMEAN rates m(months)	LIMEAN rates /Yields m(months)
		1	3	6	6	12	6	6
n (months)	3	24%						
	6	25%	13%					
	12	32%	24%	16%	18%		6%	13%
	18				21%			
	24				25%	11%		

Table 8. Johansen Cointegration Analysis (restricted constant)

		Null	Alternative	Statistic	95% critical value	90% critical value
LIMEAN	3-month rate 3 months ahead (p=4)	r = 0 r = 1	r = 1 r = 2	24.1291 1.6608	15.672 9.243	13.752 7.525
	6-month rate 6 months ahead (p=7)	r = 0 r = 1	r = 1 r = 2	17.718 5.4493	15.672 9.243	13.752 7.525
Yields	6-month rate 6 months ahead	r = 0 r = 1	r = 1 r = 2	36.5349 1.6083	15.672 9.243	13.752 7.525
	6-month rate 12 months ahead	r = 0 r = 1	r = 1 r = 2	18.4123 1.8141	15.672 9.243	13.752 7.525
	6-month rate 18 months ahead	r = 0 r = 1	r = 1 r = 2	7.6918 2.0264	15.672 9.243	13.752 7.525
Yields/ LIMEAN rates	6-month rate 6 months ahead (p=7)	r = 0 r = 1	r = 1 r = 2	12.0585 2.7193	15.672 9.243	13.752 7.525
LIMEAN rates /Yields	6-month rate 6 months ahead (p=6)	r = 0 r = 1	r = 1 r = 2	28.4786 2.4674	15.672 9.243	13.752 7.525

Note: the ECM lag length is given by p.
r is the number of cointegrating vectors.

Table 9a. Long and short-run Relationship and Point Estimates of the Error Correction Term

		Test		Statistic	Point Estimate
LIMEAN	3-month rate 3 months ahead (p=4)	$\beta_0 = 0$ $\beta_1 = 1$	$\chi^2(2)$	3.8308	
		$\beta_1 = 1$	$\chi^2(1)$	3.2384	1.0628
		$\beta_0 = 0$	$\chi^2(1)$	2.4716	-0.57711
		$\alpha_r = -1$	$\chi^2(1)$	46.2332*	-0.12631
		$a_{r,i} = b_{r,i} = 0$	$\chi^2(6)$	5.0811	
	6-month rate 6 months ahead (p=7)	$\beta_0 = 0$ $\beta_1 = 1$	$\chi^2(2)$	4.2686	
		$\beta_1 = 1$	$\chi^2(1)$	4.1414**	1.1231
		$\beta_0 = 0$	$\chi^2(1)$	3.8528	-1.2494
		$\alpha_r = -1$	$\chi^2(1)$	529.7041*	0.00122
		$a_{r,i} = b_{r,i} = 0$	$\chi^2(12)$	12.5506	
Yields	6-month rate 6 months ahead	$\beta_0 = 0$ $\beta_1 = 1$	$\chi^2(2)$	15.446*	
		$\beta_1 = 1$	$\chi^2(1)$	11.9501*	1.5364
		$\beta_0 = 0$	$\chi^2(1)$	8.7331*	-4.3279
	6-month rate 12 months ahead	$\beta_0 = 0$ $\beta_1 = 1$	$\chi^2(2)$	7.0187*	
		$\beta_1 = 1$	$\chi^2(1)$	6.2705*	1.9393
		$\beta_0 = 0$	$\chi^2(1)$	5.3757*	-8.3351
LIMEAN rates /Yields	6-month rate 6 months ahead (p=6)	$\beta_0 = 0$ $\beta_1 = 1$	$\chi^2(2)$	14.3323*	
		$\beta_1 = 1$	$\chi^2(1)$	8.7664*	1.1479
		$\beta_0 = 0$	$\chi^2(1)$	11.3459*	-1.8726
		$\alpha_r = -1$	$\chi^2(1)$	53.2477*	-0.17681
		$a_{r,i} = b_{r,i} = 0$	$\chi^2(10)$	5.7296	

Notes * = the null hypothesis is rejected at the 5% level.
** = the null hypothesis is accepted at the 4.2% level.

Table 9b. Point Estimates of the Error Correction Term: $H_0 : \beta_1 = 0$

		Test		Statistic	Point Estimate
LIMEAN	3-month rate 3 months ahead (p=4)	$\beta_1 = 0$	$\chi^2(1)$	22.4523*	1.0628
	6-month rate 6 months ahead (p=7)	$\beta_1 = 0$	$\chi^2(1)$	12.2502*	1.1231
Yields	6-month rate 6 months ahead	$\beta_1 = 0$	$\chi^2(1)$	34.4017*	1.5364
	6-month rate 12 months ahead	$\beta_1 = 0$	$\chi^2(1)$	15.6460*	1.9393
LIMEAN rates /Yields	6-month rate 6 months ahead (p=6)	$\beta_1 = 0$	$\chi^2(1)$	25.4319*	1.1479

Notes * = the null hypothesis is rejected at the 5% level.

Table 10a. The single-Equation Regressions: Coefficients

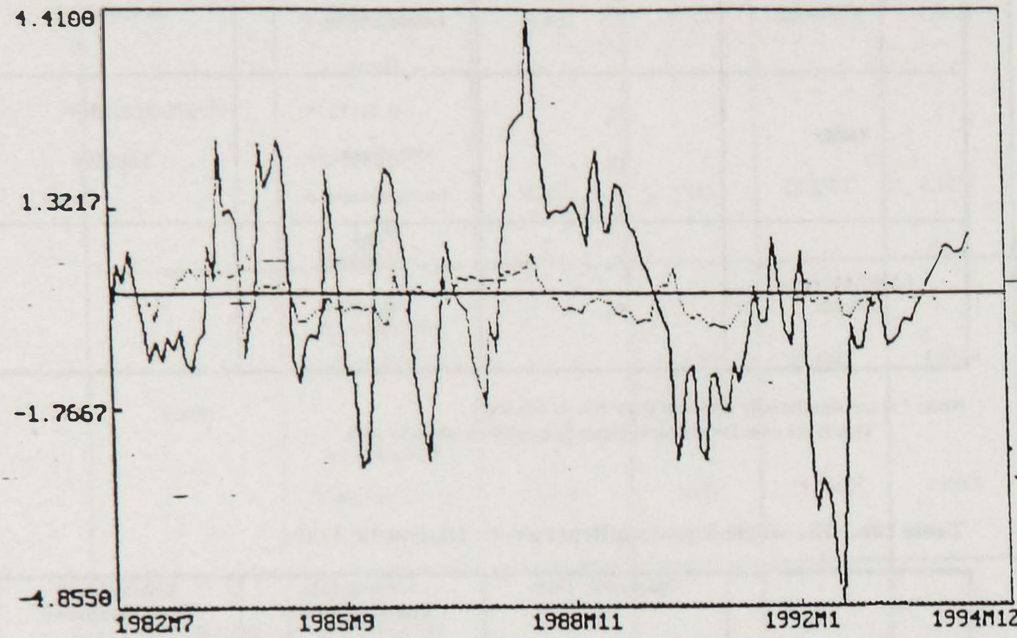
	Coefficients	6-month rate 6 months ahead	6-month rate 12 months ahead
LIMEAN	h_0	0.15552*	0.083379*
	α_r	-0.1849*	-0.9307E-3*
Yields	h_0	-0.011127*	-0.11256*
	α_r	-0.049543*	0.00369*
LIMEAN rates /Yields	h_0	0.20594*	
	α_r	-0.24576*	

Note: * = not significantly different from zero at 5% level.
This is the case for the coefficients of lagged variables as well.

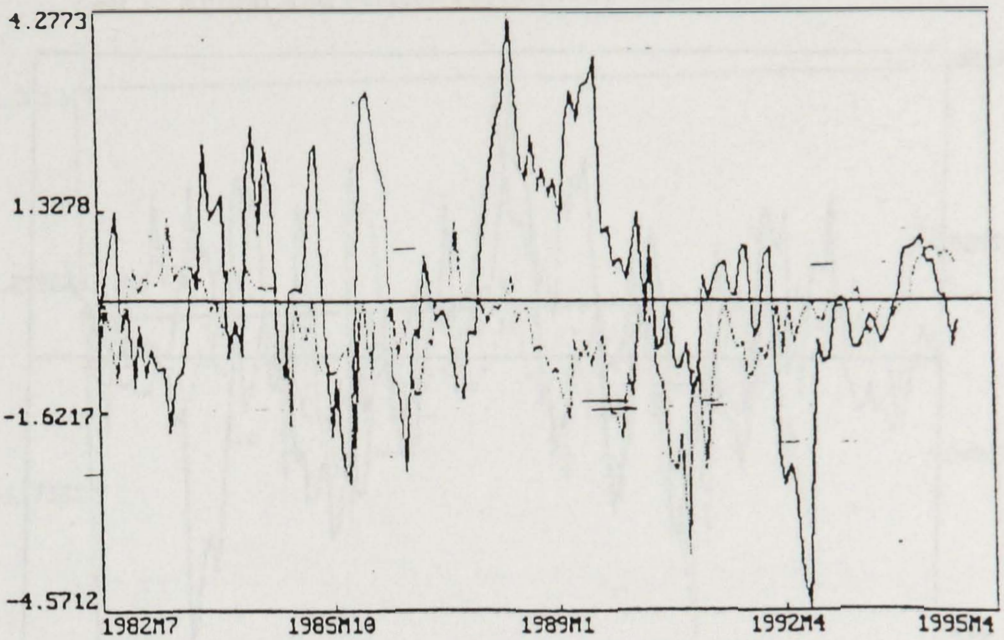
Table 10b. The single-Equation Regressions: Diagnostic Tests

	Diagnostic Tests	6-month rate 6 months ahead	6-month rate 12 months ahead
LIMEAN	*Serial Correlation*	$\chi^2(12) = 5.7307$ [.929]	$\chi^2(12) = 11.7890$ [.463]
	Functional Form	$\chi^2(1) = 0.10088$ [.751]	$\chi^2(1) = 0.30482$ [.581]
	Heteroscedasticity	$\chi^2(1) = 0.094094$ [.759]	$\chi^2(1) = 0.036417$ [.849]
Yields	*Serial Correlation*	$\chi^2(12) = 15.5913$ [.211]	$\chi^2(12) = 16.6493$ [.163]
	Functional Form	$\chi^2(1) = 0.25248$ [.615]	$\chi^2(1) = 1.2748$ [.259]
	Heteroscedasticity	$\chi^2(1) = 0.66451$ [.415]	$\chi^2(1) = 0.15716$ [.692]
LIMEAN rates /Yields	*Serial Correlation*	$\chi^2(12) = 16.0263$ [.191]	
	Functional Form	$\chi^2(1) = 1.2748$ [.259]	
	Heteroscedasticity	$\chi^2(1) = 0.15716$ [.692]	

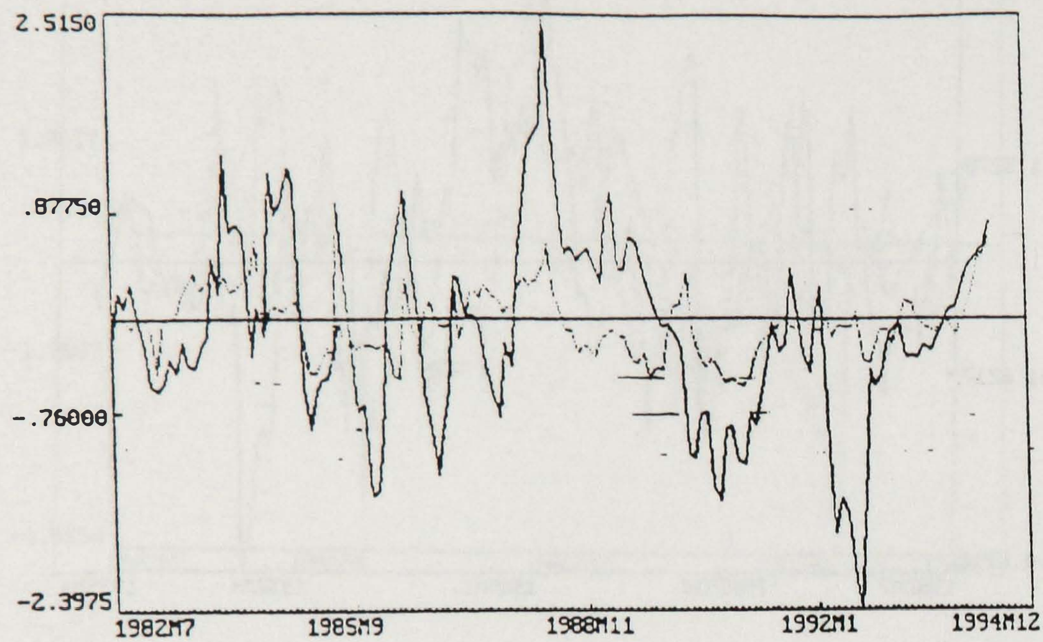
Test 1. Actual And Perfect-Foresight Spreads: 12-6 month Limean



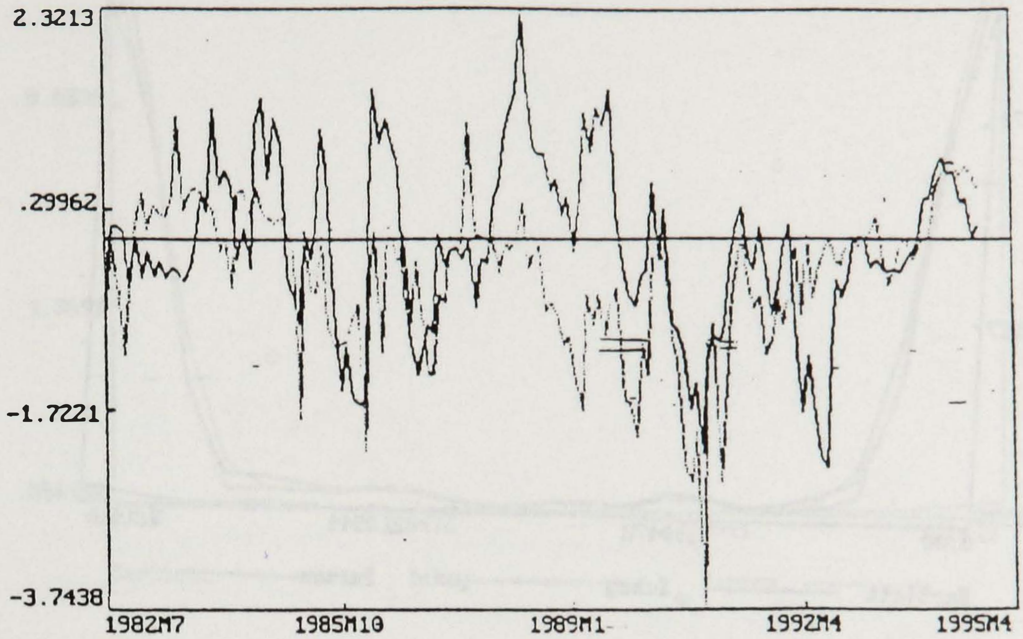
Test 1. Actual And Perfect-Foresight Spreads: 12-6 month Yields



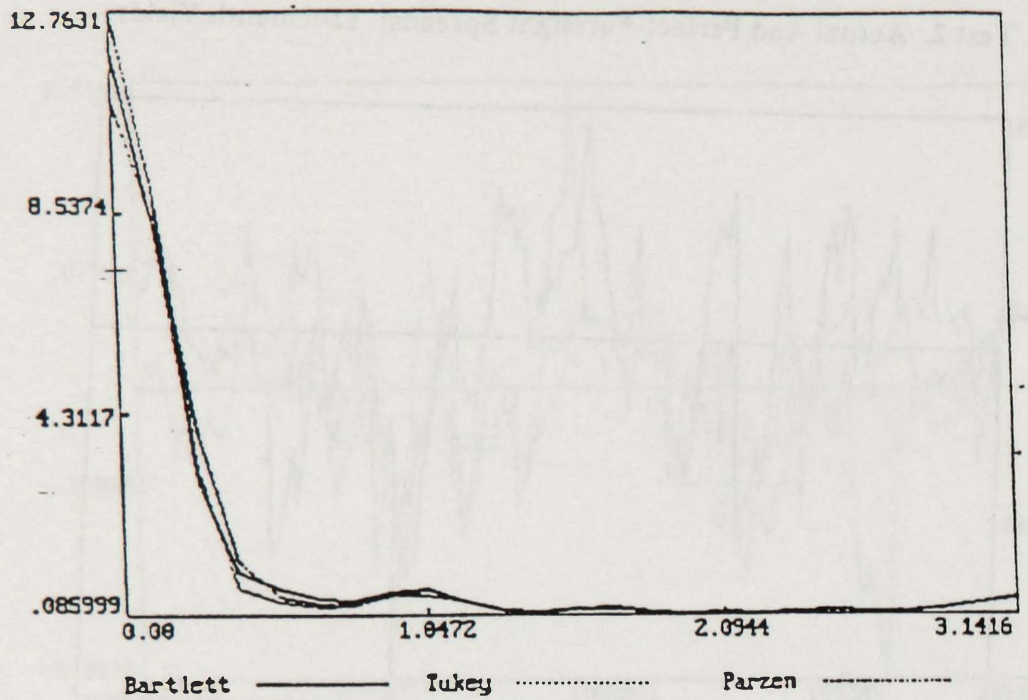
Test 2. Actual And Perfect-Foresight Spreads: 12-6 month Limean



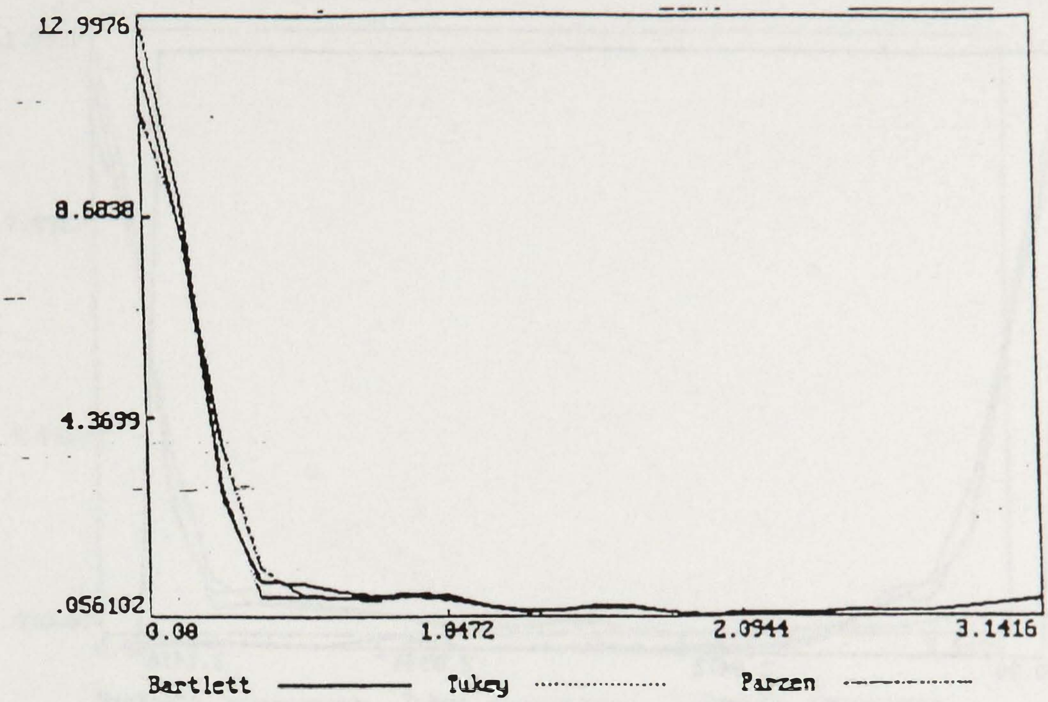
Test 2. Actual And Perfect-Foresight Spreads: 12-6 month Yields



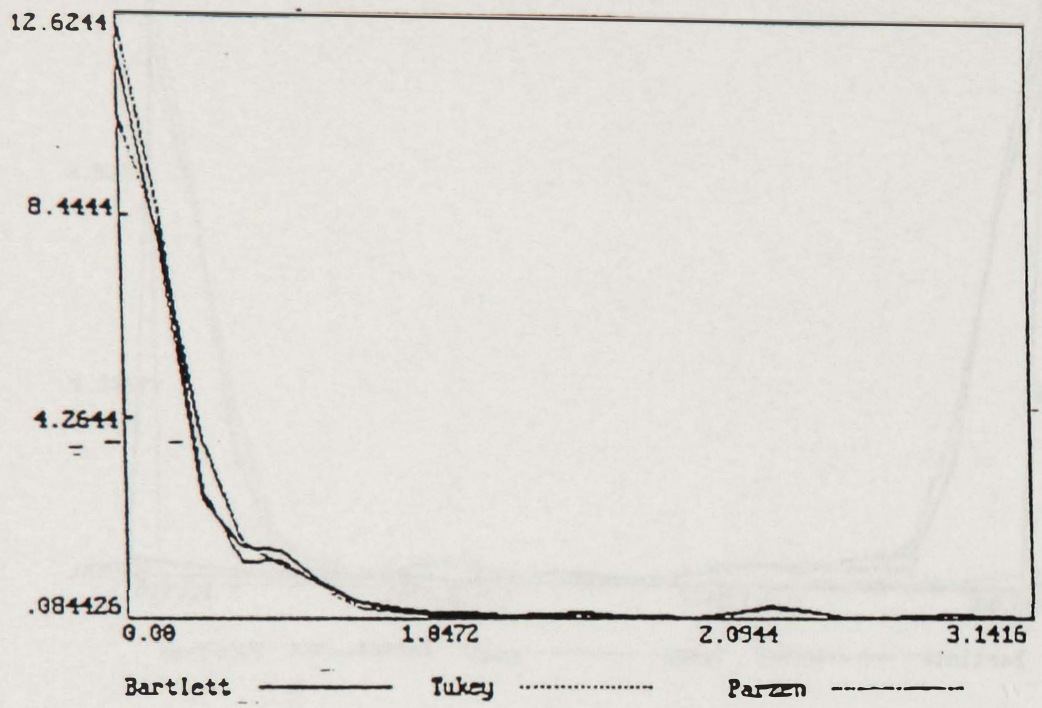
Various Estimates of Standardised Spectral Density of S(24, 18)



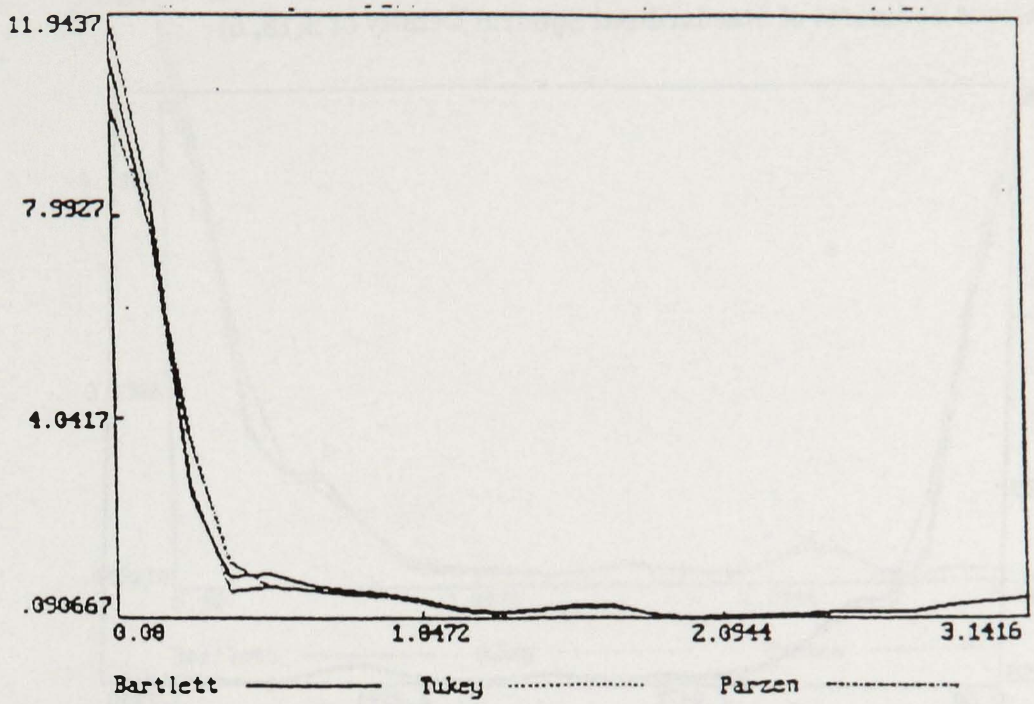
Various Estimates of Standardised Spectral Density of S(24, 12)



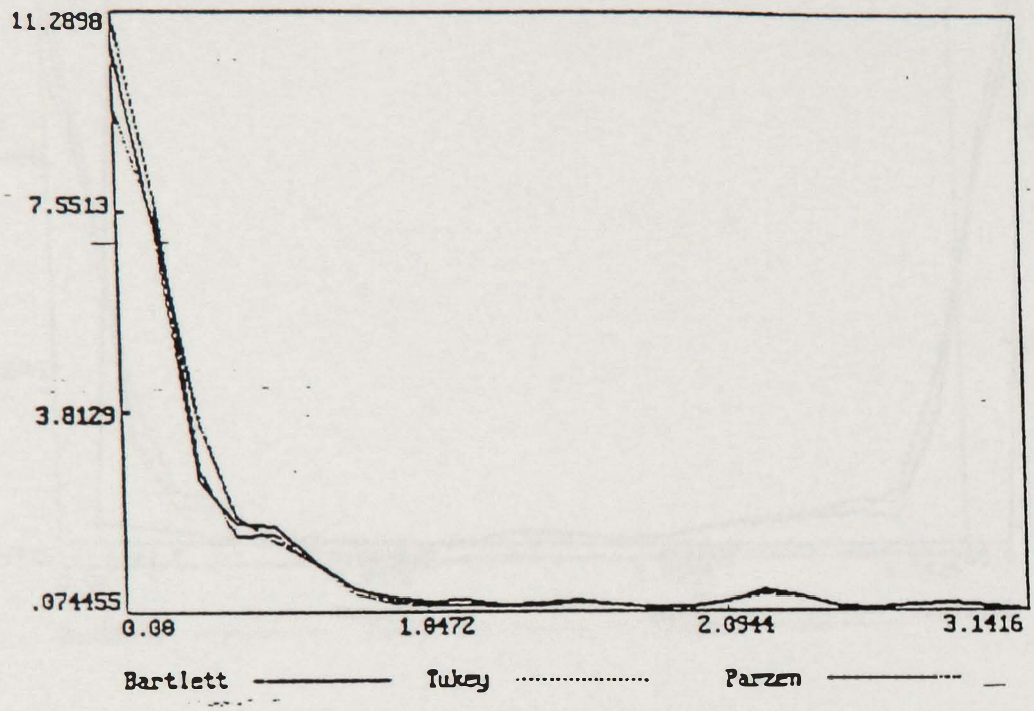
Various Estimates of Standardised Spectral Density of S(24, 6)



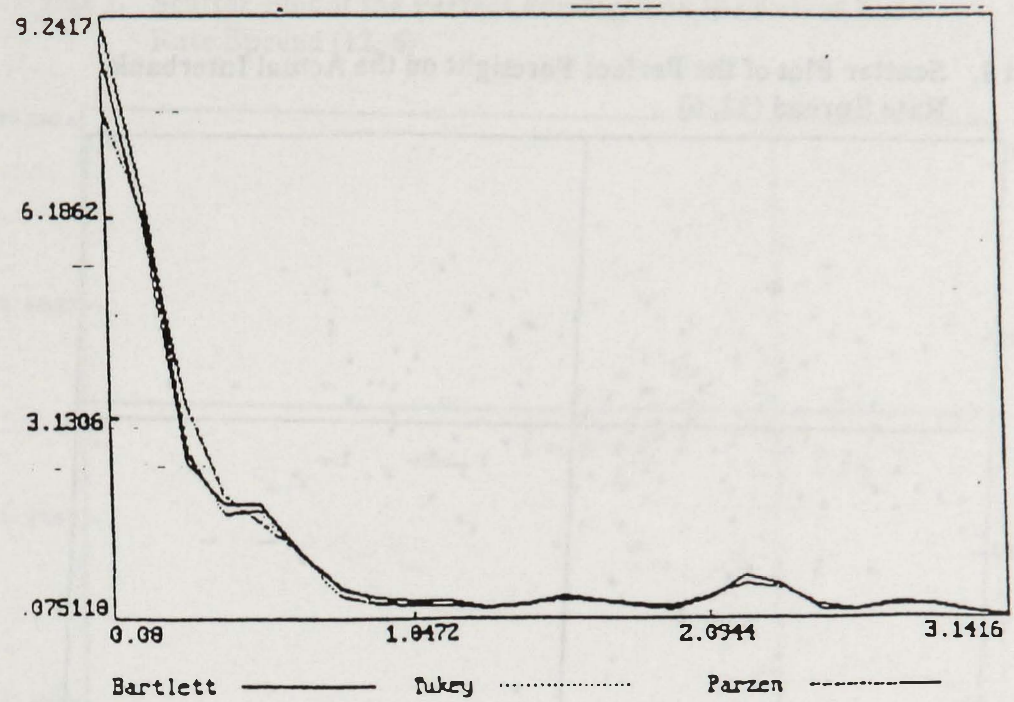
Various Estimates of Standardised Spectral Density of S(18, 12)



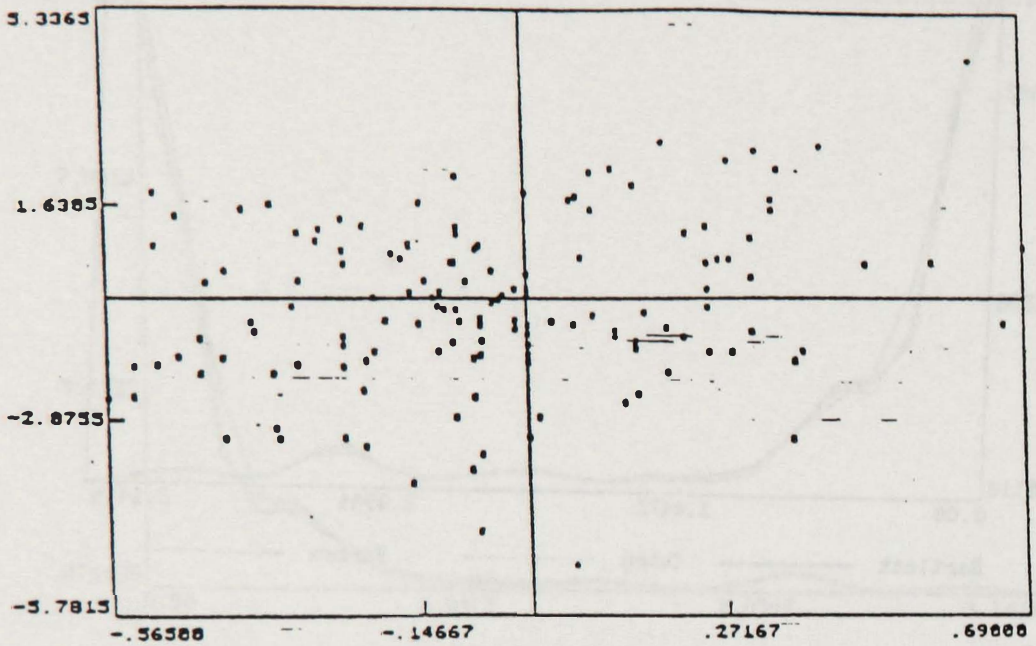
Various Estimates of Standardised Spectral Density of S(18, 6)



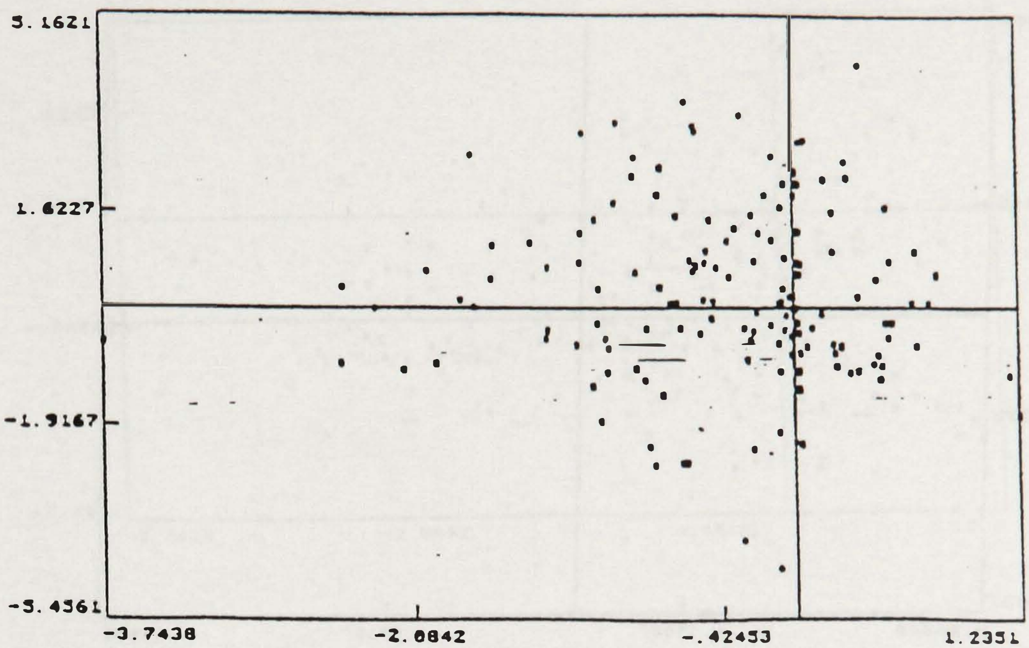
Various Estimates of Standardised Spectral Density of S(12, 6)



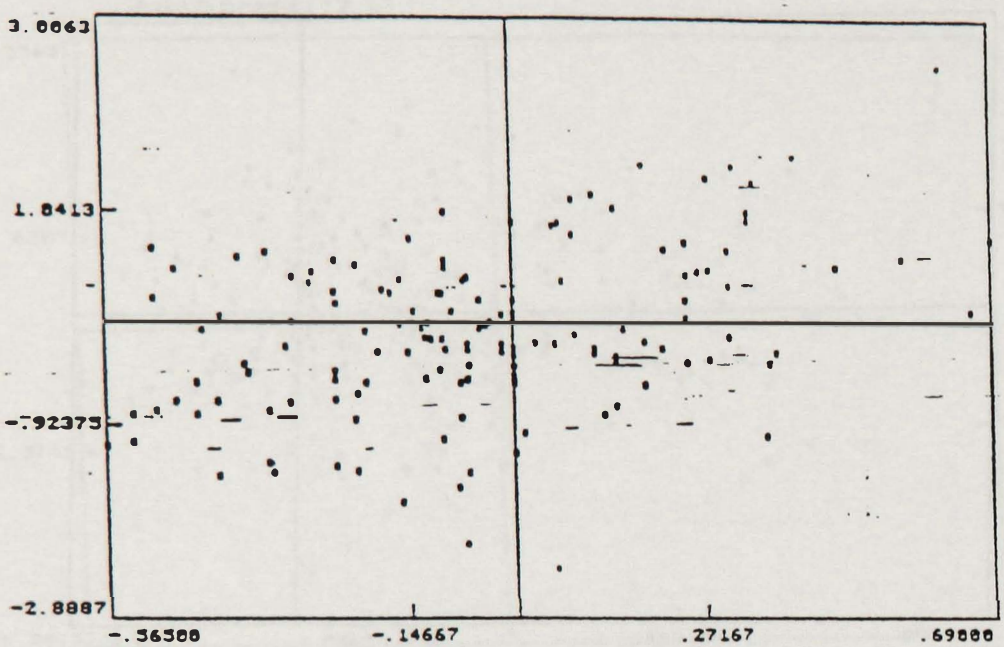
Test 1. Scatter Plot of the Perfect Foresight on the Actual Interbank Rate Spread (12, 6)



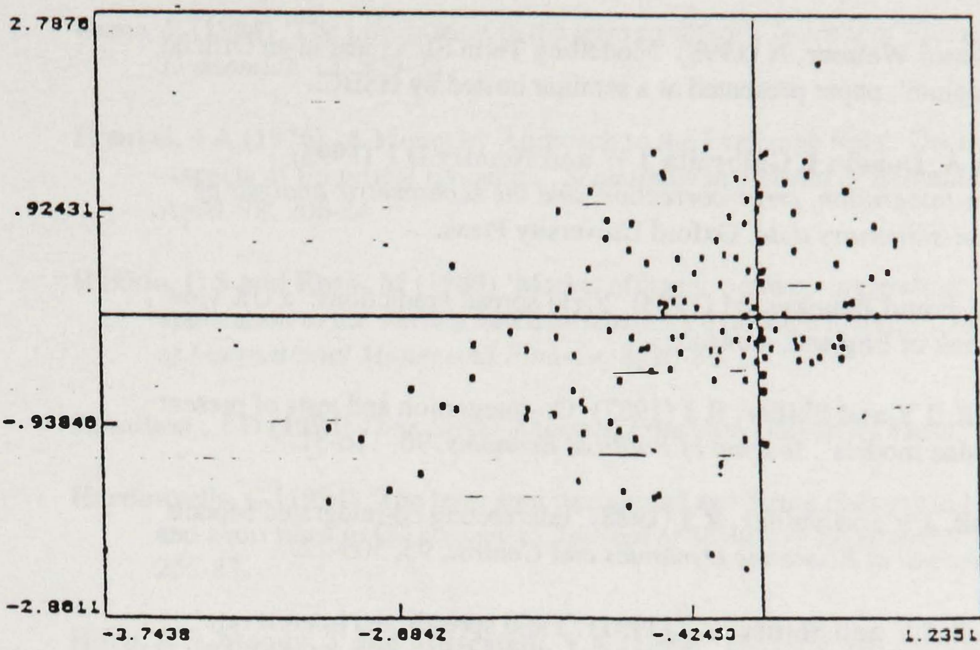
Test 1. Scatter Plot of the Perfect Foresight on the Actual Yield Rate Spread (12, 6)



Test 2. Scatter Plot of the Perfect Foresight on the Actual Interbank Rate Spread (12, 6)



Test 2. Scatter Plot of the Perfect Foresight on the Actual Yield Rate Spread (12, 6)



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